A Magnetically Driven Interface CME Generator Model at CCMC

Igor V. Sokolov, University of Michigan

…and application to modeling Solar Energetic Particles

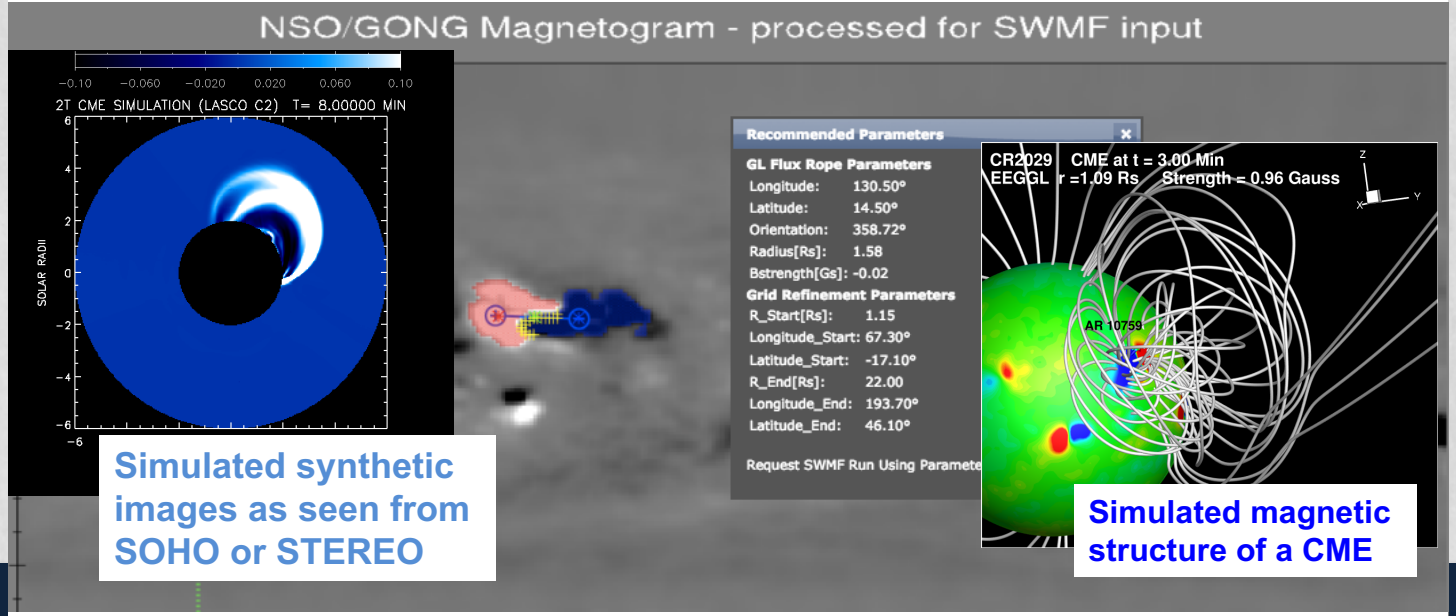
The First-Principles Model of CME Magnetic Structure and Evolution is Available to the World

StereoCAT CME Analysis Tool

EEGGL Eruption Event Generator by Gibson & Low
(delivered as a package)

SWMF AWSoM-R

Global MHD simulations of CME plasma and magnetic structure eruption and propagation through space
24 user simulations executed since Nov 2016



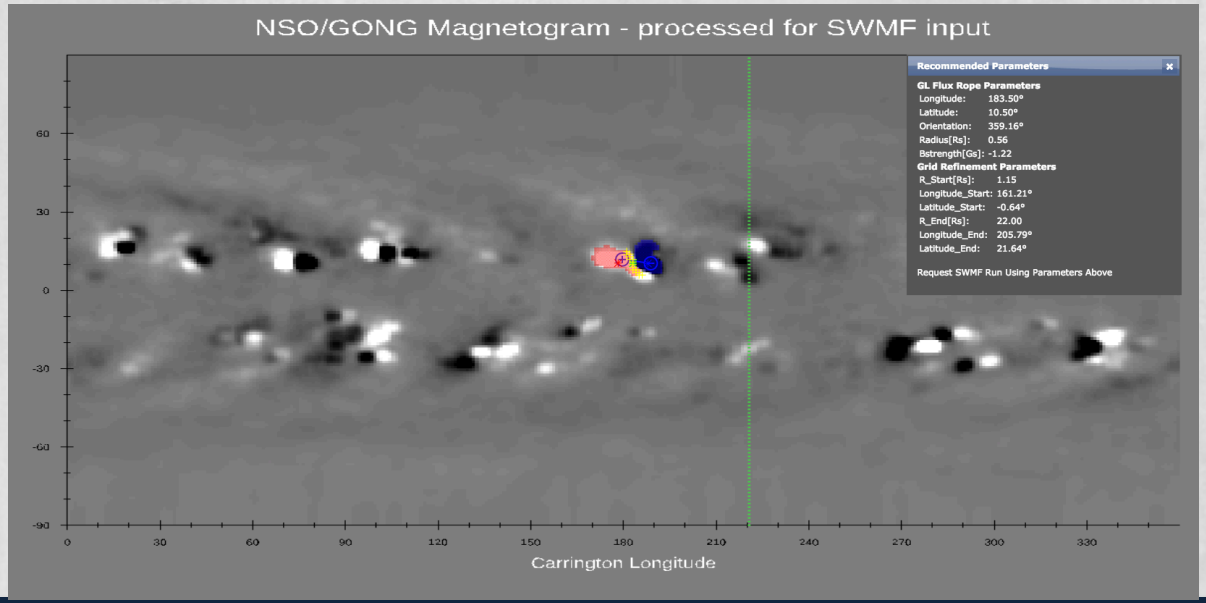
Simulated synthetic images as seen from SOHO or STEREO

Simulated magnetic structure of a CME

SWMF Team: Igor Sokolov, Meng Jin (UMich) CCMC: R. Mullinix, A. Taktakishvili

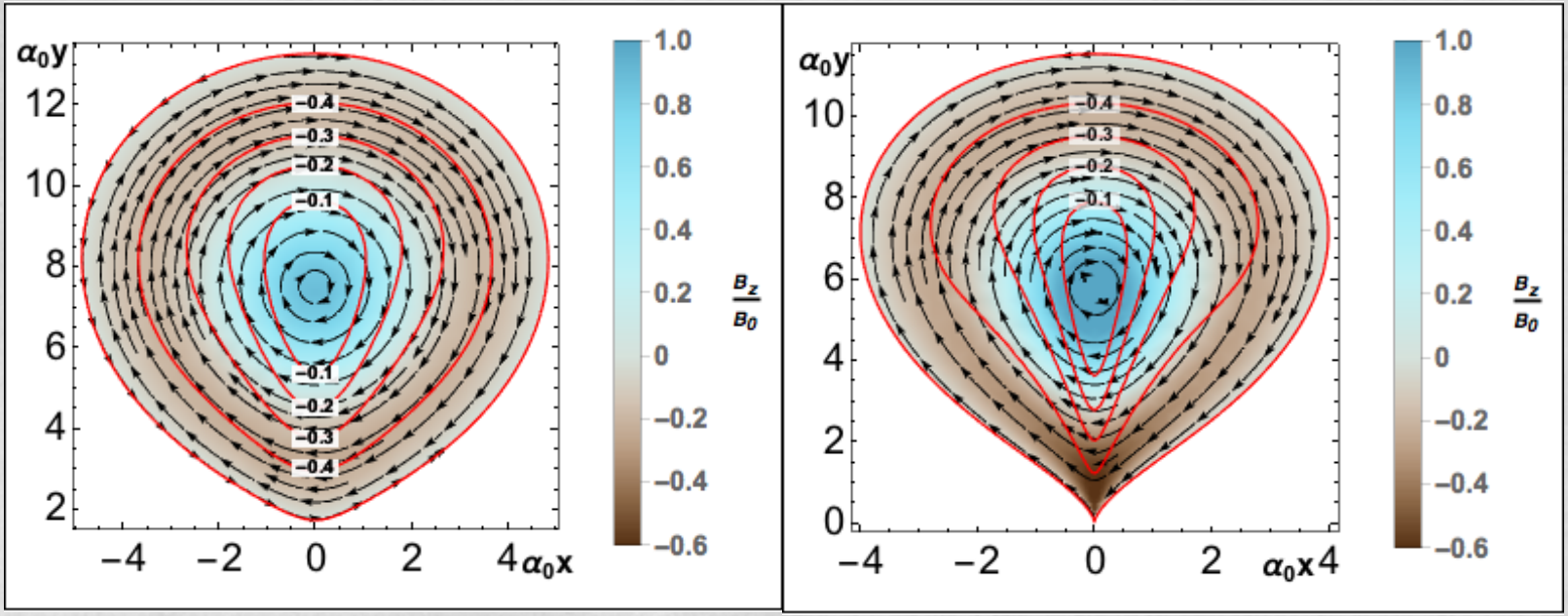
MHD Simulation. CME Simulation

Initiating CME simulation with Eruptive Event Generator using Gibson-Low flux rope (EEGGL)



MHD Simulation. CME Simulation

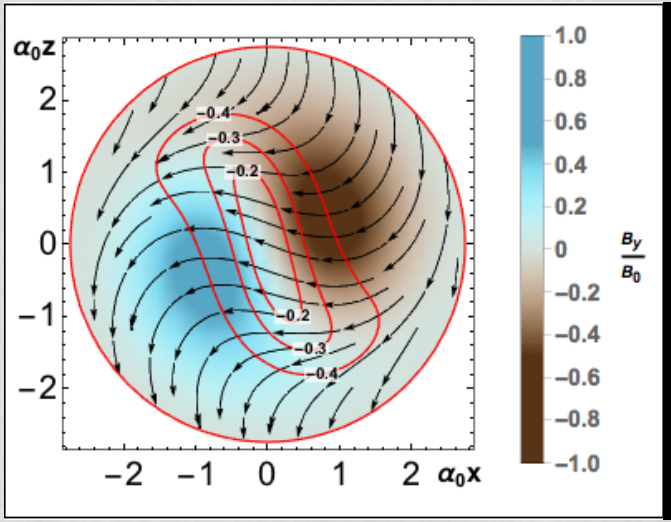
- To initiate CME in simulation - impose Gibson-Low (GL) flux rope
- Apply stretching transformation (Gibson and Low 1998, Shiota and Kataoka 2016)
- Described in the commentary by Borovikov et al submitted to the JGR (2017)

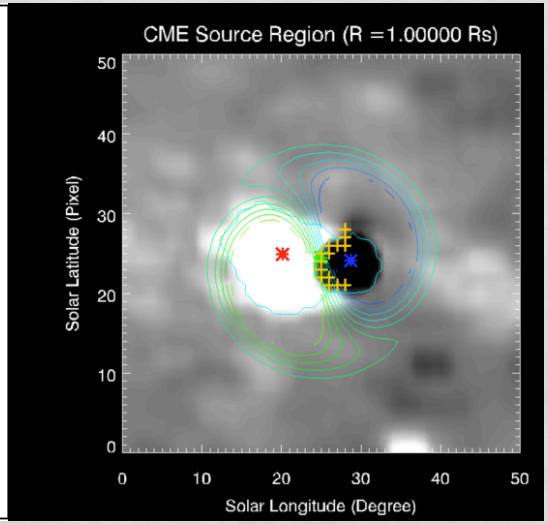


MHD Simulation. CME Simulation

Initiating CME simulation with EEGGL

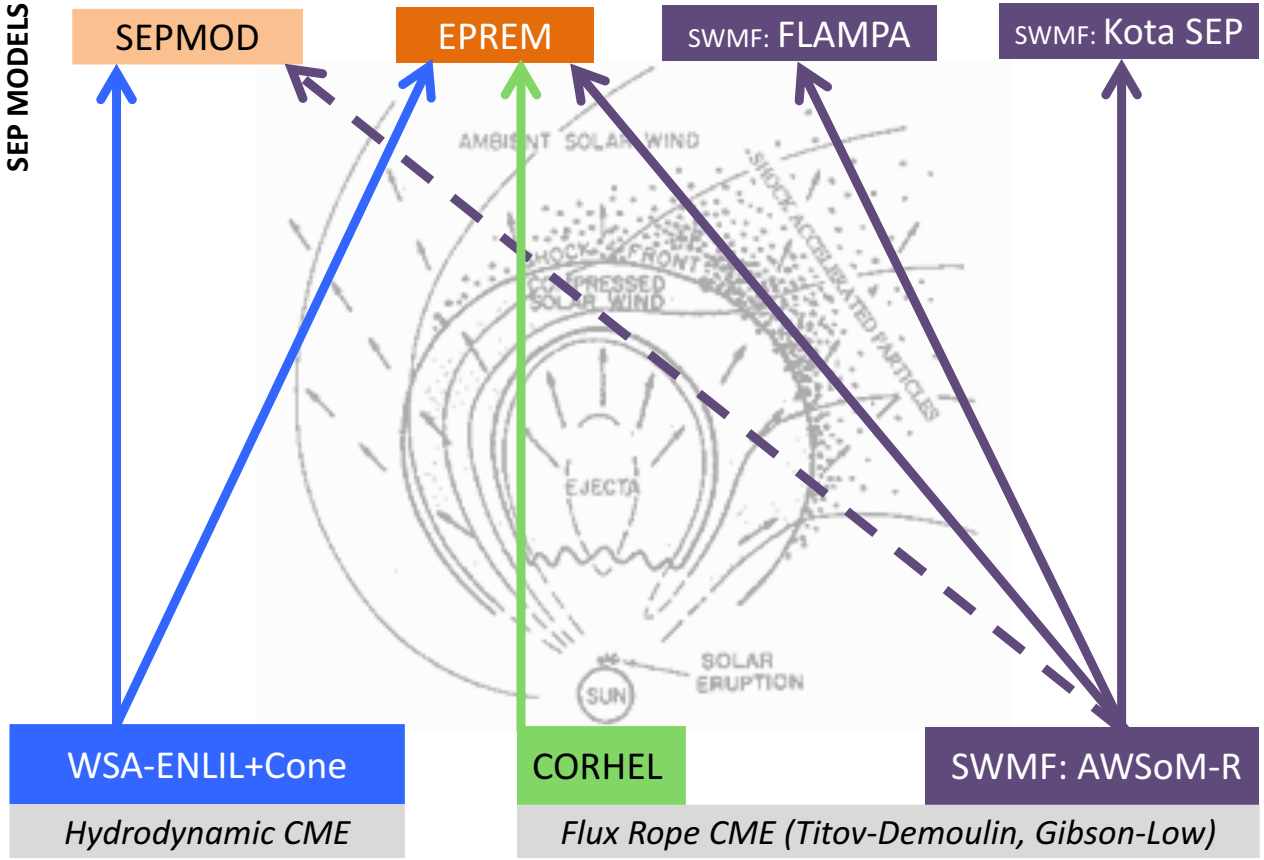
- Based on magnetogram (boundary condition), parameters of GL flux rope are computed





Towards coupled heliosphere and SEP models

CCMC is making steps towards offering a system to run SEP models driven by a variety of heliospheric models.



Modelers: N. Arge, D. Odstrcil, J. Luhmann, J. Linker, N.Schwadron, M. Gorby, I.Sokolov

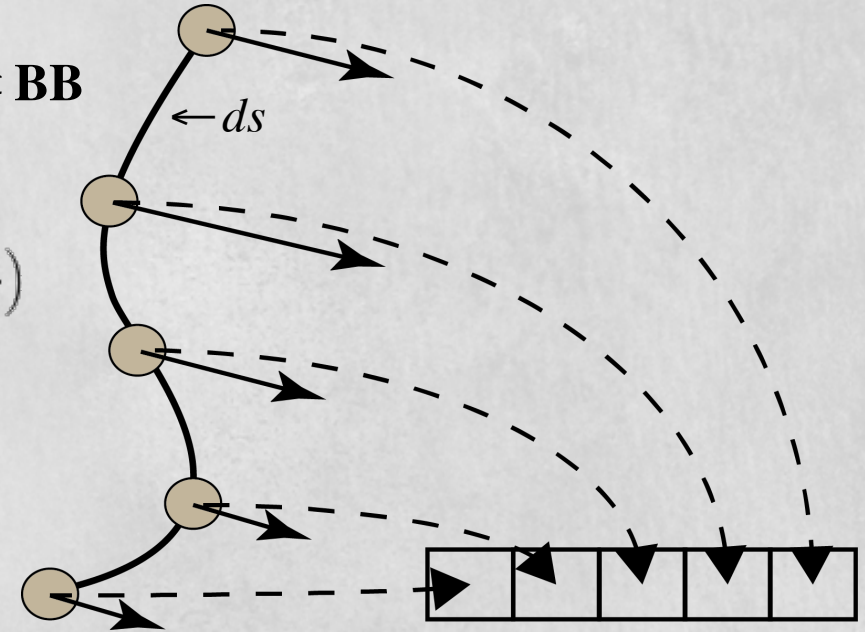
Field-Line-Advection Model for Particle Acceleration (FLAMPA)

Parker equation or the focused transport equation may be expressed in the Lagrangian coordinates (Sokolov et al 2004, Kota et al 2005)

$$\frac{\partial f}{\partial t} + \mathbf{u}\cdot\nabla f - \frac{1}{3}(\nabla\cdot\mathbf{u})\frac{\partial f}{\partial \log p} = \nabla\cdot(\kappa\cdot\nabla f), \quad \kappa \propto \mathbf{BB}$$

$$\frac{Df}{Dt} + \frac{1}{3}\frac{D\ln\rho}{Dt}\frac{\partial f}{\partial \ln p} = B\frac{\partial}{\partial s}\left(\frac{\varkappa}{B}\frac{\partial f}{\partial s}\right)$$

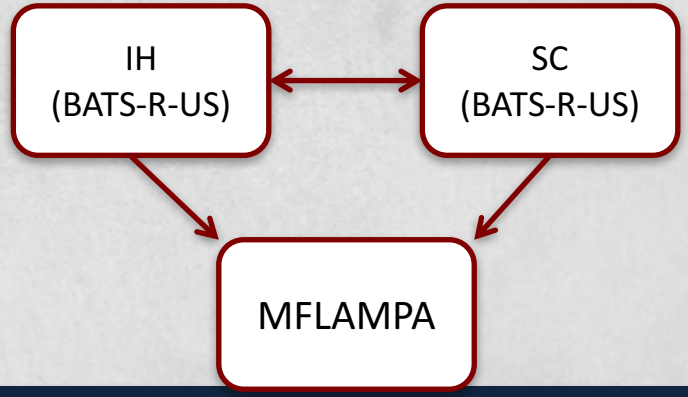
Reduction to single spatial dimension transforms spatially 3-D problem to multitude of spatially 1-D problems

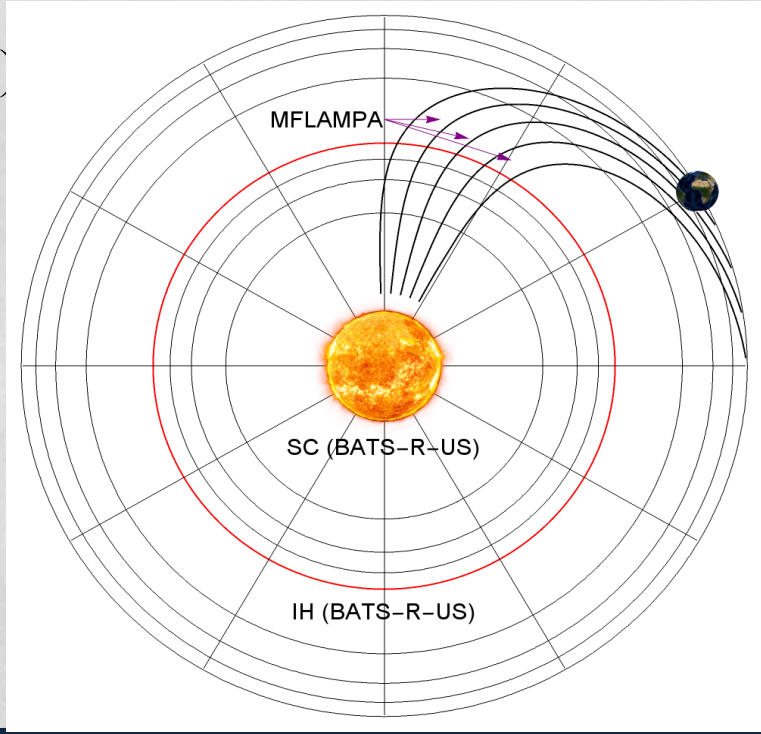


Technology with Many Field Lines. Design

A forecasting framework:

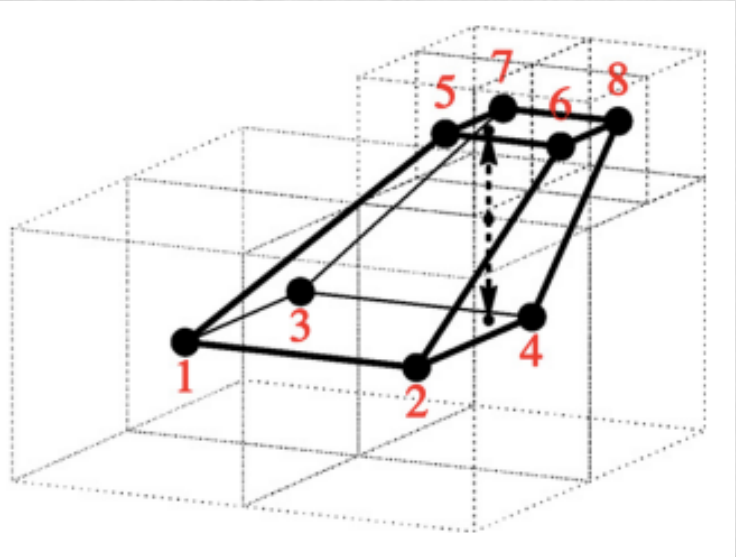
- Model of Solar Corona and Inner Heliosphere (IH)
  - Block-Adaptive-Tree-Solar-wind-Roe-type-Upwind-Scheme (BATS-R-US)
- Kinetic particle model
  - Multi-Field-Line Advection Model of Particle Acceleration (M-FLAMPA)

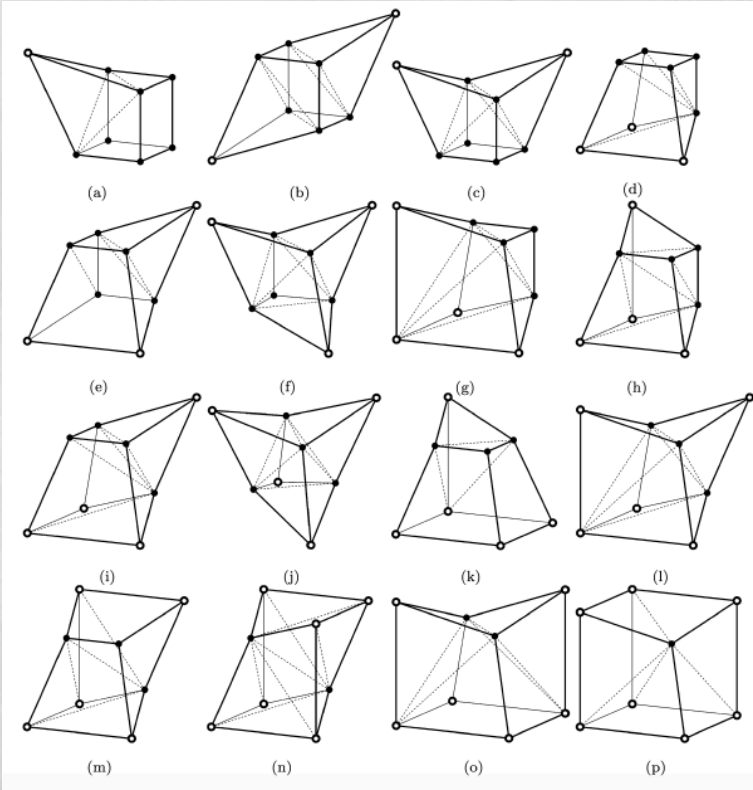




Technology with Many Field Lines. Design

Line extraction on AMR grids must
be continuous: avoid spurious shocks

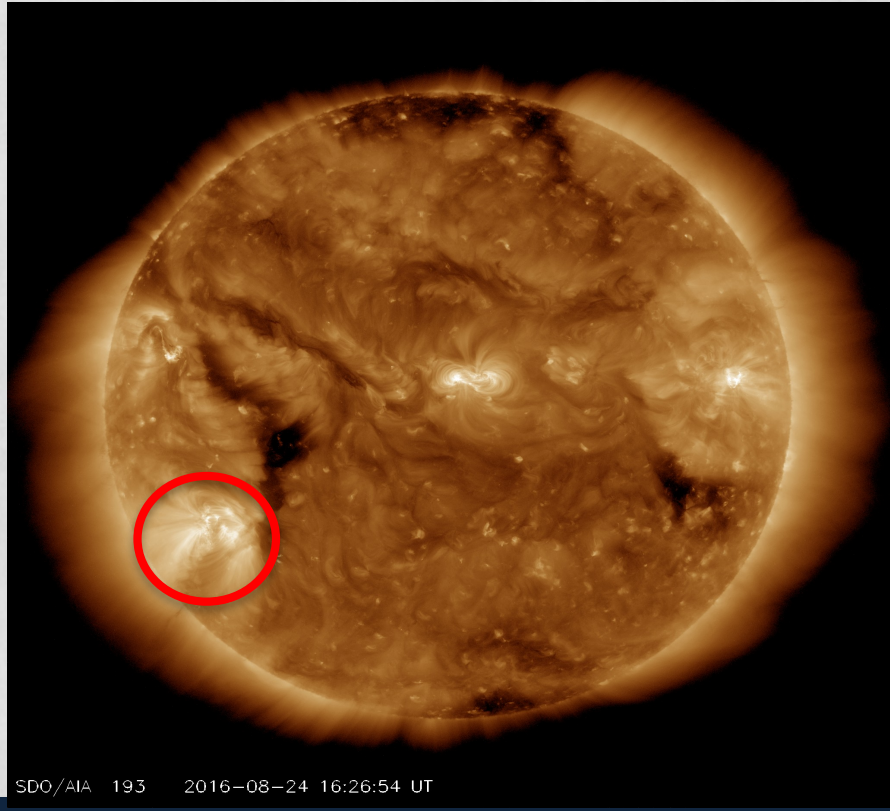




Technology with Many Field Lines

Example of operation:

- For an observed magnetogram simulate steady state corona and solar wind
- Extract field lines starting from an active region of choice



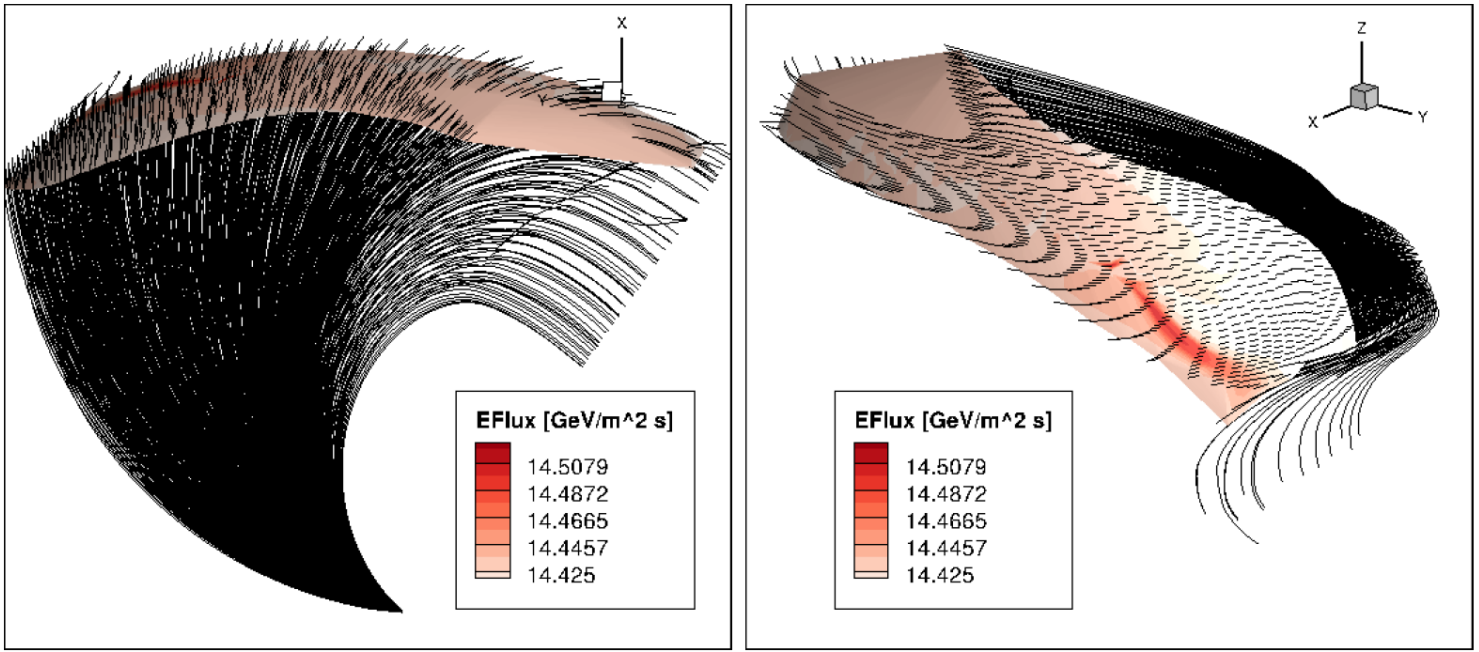


Figure 6.4: The extracted field lines and their mapping onto 1 AU sphere. The conditions are steady, the shape of the field lines is similar, at least qualitatively to the classic Parker's spiral. Triangulation on footprints of field lines on the 1 AU sphere allows interpolating the simulated data to obtain, for example, the energy flux carried by SEPs at 1 AU (shown in color). The mapped region has an irregular shape, which is expected due to non-trivial geometry of field lines.